

CHANGING PATTERNS OF RAINFALL IN SOKOTO STATE, NIGERIA (1926-2015)

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ABSTRACT

The study of the changing patterns of rainfall of any particular place on earth is a veritable tool in monitoring the potential impact of Climate change and variability over the time. This study examines the changing patterns of rainfall in Sokoto for a period of 90 years (1926-2015). The study used monthly rainfall data collected from the archives of the Nigerian Meteorological Agency (NIMET) for Sokoto. The data was analyzed using coefficient of variation (C.V) and linear regression trend line. The results show that the rainfall in Sokoto is increasing at the rate of 47.71mm per decade. Result further shows a general downward trend in the annual rainfall over the 90 year period but the decrease is statistically insignificant ($R^2 = 0.0261$). The annual rainfall was highly variable during the period 2006-2015 (C.V = 41.8%) and less variable during 1996-2005 (C.V = 9.5%). This study concludes that there is change in the patterns of decadal, annual and numbers of monthly rainfall occurrence over the ninety years period in Sokoto State. The discrepancy that arises between the decadal and the annual rainfall trend over the period is attributed to the catastrophic droughts of 1940s, 1970s and 1980s that led to a marked reduction in the Sahelian rainfall and the recovery that began from 1998 up to date. This study thus recommends adequate and accurate seasonal rainfall predictions to farmers and other important sectors of the Nigerian economy that have strong nexus with rainfall. If the current rainfall trends continue, there will be the need for more functional irrigation schemes to boost crop production in the State.

Keywords: Changing, Pattern, Decadal-changes, Trend, Rainfall

Introduction

A better understanding of the changing patterns of rainfall over a considerable number of years is a veritable tool in monitoring the potential impact of Climate Change and variability, especially on the rain-fed agriculture. The patterns of daily,

monthly, annual and decadal changes in the rainfall will no doubt affect agricultural production and other important aspects of our environment that depend on rainfall for proper functioning. However, several attempts have been made to study the

patterns of rainfall in Africa in an attempt to understand the rainfall pattern in the continent (Grove, 1972; Grove, 1973; Ayoade 1974; Kerr, 1985; Ojo, 1986a; Lamb, 1980; Ojo, 1986b; Nicholson, *et al.*, 1981 and Nicholson 1983 and Norrgard, 2017). However, a divergent opinion has been reported to have aroused from the results of these studies about the nature and characteristics of the rainfall variability and climate change on the continent (Umar, 2012). According to Lamb (1973 cited in Umar 2012), the Sahelian droughts “have a long history and that it is not likely to disappear in the near future”. Winstanley (1973 cited in Umar, 2012), also noted that the downward trend in West Africa will continue for 50 years. contrary to the claim of Winstanley (1973 cited in Umar, 2012), that the Sahelian drought will persist for quite long time, other scientists consider the drought as unusual in terms of the recent past but necessarily deviating from the longer term probabilities. In fact, Landsberg (1975 cited in Umar, 2012) concludes that Sahelian drought of 1970s should be accepted as part of the normal climate of the region.

In an attempt to bridge the gap in literature and to minimize the disagreement in the results about the real patterns of rainfall in Nigeria with a view to designing a robust mechanisms to tackle the vagaries of climate Change, a number of studies have also been carried out to examine the patterns of rainfall across Nigeria (Umar and Bako, 2018; Adefolalu, 1986; Udjugo, 2005; Anyadike, 1993; Umar, 2013, 2012 and Umar and Samaila, 2017)). The studies mentioned only focused on the patterns of rainfall at the continental and national levels while some only focused on the monthly rainfall variability. Hence, the need to narrow the scope of the study of changing patterns of rainfall to a local scale. This will pave way for

a better understanding of the changing patterns of rainfall in different part of Nigeria for proper planning towards assisting the rain-fed agriculture. This prompts the idea of examining the changing patterns of rainfall in Sokoto State over a period of ninety years (1926-2015).

The previous studies in Sokoto revealed that Sokoto State is one of the Semi-Arid regions of Nigeria bedeviled with the negative consequences of Climate Change and variability. The evidence of Climate Change on the various aspect of human endeavour has been proved in Sokoto (Umar, 2012, 2013; Bashar and Aminu, 2013; Idris, 2013; Samaila, 2013; Abubakar, 2013, Oppon-Kumi, 2013; Ilya, 2013; Ma’arufdeen, 2013; Sa’adu, 2013; Fada, 2013 and Jibrillah, 2013).. However, none of these studies specifically focused on the changing pattern of rainfall in Sokoto State. Umar and Ismaila (2017) studied monthly rainfall variability as a further evidence of Climate Change in Sokoto State for the period of 1926 to 2015 and the aim of their study is on the monthly rainfall variability without much emphasis on the decadal and annual rainfall pattern. Therefore, this study fills the gap existing in literature about the rainfall patterns in Sokoto State with a view to assisting farmers and other stakeholders in the agricultural sector and other sectors that are very much concern about weather and climate to design robust mechanisms to tackle the vagaries of Climate Change and rainfall variability in the region.

Methods of the Study

Study Area

Sokoto is city located in the extreme northwest of Nigeria, near the confluence of the Sokoto River and the Rima River. As of 2006, it has a total population of 427,760. Sokoto is the capital of the modern day Sokoto State (<https://www.wikipedia>

.org/wiki/en m/sokoto/, 2018). Sokoto State is located approximately on latitude 13°.01'

of the equator and longitude 5°.15' of the Greenwich meridian (Figure 1).

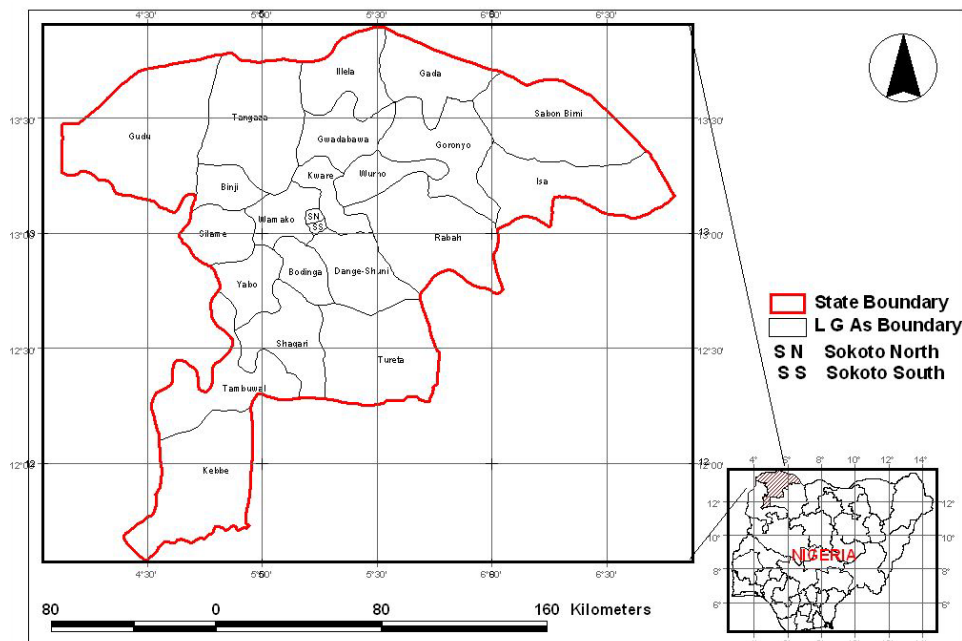


Figure 1: Map of Sokoto State

Source: Macmillan secondary School Atlas (2000)

Climate of Sokoto

Sokoto is in the dry Sahel surrounded by sandy savannah and isolated hills. It has an average temperature of 28°C (82.9°F). Sokoto is one of the hottest cities in the World. However, the maximum daytime temperatures are generally under 40°C (101.0°F) most of the year and dryness makes the heat unbearable (<https://www.wikipedia.org/wiki/en m/sokoto/>, 2018). The warmest months are February to April where daytime temperature can exceed 45°C (113.0°F). The highest recorded temperature is 47.2°C (117.0°F), which is also the highest recorded temperature in Nigeria. The rainy season is from June to October during which showers rarely last long and are a far different from the regular torrential showers known in many tropical regions.

Economic Activities of Sokoto People

Over eighty percent (80%) of the inhabitants of Sokoto practice one form of agriculture or another. They produce crops such as millet, guinea corn, maize, rice, potatoes, cassava, groundnuts and beans for subsistence and produce wheat, cotton and vegetables for cash. Local crafts such as blacksmithing, weaving, dyeing and carving, leather works also play an important role in the economic life of the people of Sokoto. As a result, different places like Makera, Marina, Takalmawa and Majema become important place. sokoto ios also one of the fish producing areas of the country. Thus a lage number of people along the river basin engage in fishing as well (<https://www.wikipedia.org/wiki/en m/sokoto/>, 2018)

This study used ninety (90) years monthly rainfall data collected from the archives of the Nigerian Meteorological Agency. The entire data were analyzed using coefficient of variation (C.V) to ascertain the decadal rainfall variability and linear regression trend line.

$$CV = SD / \bar{X} \times 100 \text{----- (1)}$$

Where SD = Standard deviation, $\bar{X}$ = mean

The regression equation is:

$$y = a + bx \text{----- (2)}$$

Where 'a' is the intercept of the line on y-axis, 'b' is the regression coefficient representing the slope of the line, y is the dependent variable, annual rainfall and x is the independent variable, i.e time (year). The graphs of regression trend lines were plotted showing the regression trend lines and the exponential equations as well as the Coefficient of determination (R^2) to determine the trend of rainfall over the ninety years period (1926-2015). The analysis was done through the use of Microsoft Excel. The results of analysis were presented in tables and charts for better understanding.

Results and Discussion

Inter-decadal variability of rainfall in Sokoto

The detail of the inter-decadal variability of rainfall in Sokoto from 1926 to 2015 is contained in Table 1. The Inter-decadal variability of rainfall shows that, the amount of annual rainfall in Sokoto is increasing at the rate of 47.71mm per decade. It is also evident from Table 1 that seven (6) decades out of the nine decades recoded negative

departure from the long-term mean of 676.6mm. The remaining three decades (1926-1936, 1976-1985 and 1986-1995) witnessed positive departure from the long-term mean of 676.6mm. The result in Table 1 reveals that rainfall was highly variable during the period of 2006-2015 in Sokoto. The period 2006-2015 has the highest coefficient of variation (41.8%) compared to other decades. The sixth decade and the second decade followed in terms of the high rainfall variability with C.V of (22.0% and 21.04%) respectively. Other decades have coefficient of variation of less than 20% which means the rainfall is less variable in those decades. The decade with the least coefficient of variation is 1996-2005 with C.V. of (9.5%). That means the period 1996-2005 recorded the least rainfall variability over the ninety years period (1926-2015) in Sokoto. From the forgoing, the period 2006-2015 is the worst in terms of rainfall instability and reliability in Sokoto.

By implication, the instability in rainfall affects rain-fed agriculture and other important sectors that depend on steady rainwater (15). On the contrary, the period 1996-2005 with the lowest C.V. recorded the highest rainfall stability over the ninety years (1926-2015) in Sokoto. When rainfall is stable, it means rainfall is reliable for agricultural activities. As such, it enhances proper cultivation of land for rain-fed agriculture and may eventually lead to a bumper harvest by the farmers if other factors are not the constraint.

Table 1: Inter-Decadal Variability of Rainfall in Sokoto 1926-2015

Decade	Decadal Mean (mm)	SD (mm)	C.V (%)	Decadal changes (mm)	Difference from the long-term average of 676.6 (mm)	Year with <-10% departure	Years with >+10% departure
1926-1935	676.41	135.2	19.9	-	-0.19	1926, 1928, 1934	1927, 1929, 1930, 1932, 1933 & 1935
1936-1945	707.04	148.8	21.04	30.63	30.44	1941, 1942.	1936, 1939,

						1945	
1946-1955	774.59	143.4	18.5	67.55	97.99	1947, 1951	1946, 1948, 1950, 1954.
1956-1965	772.48	134.9	17.5	-2.11	95.88	1959.	1957, 1958, 1960, 1965,
1966-1975	704.3	101.4	14.4	-68.18	27.7	1968, 1971, 1972, 1973, 1974, 1975.	NIL
1976-1985	618.23	136.2	22.0	-86.07	-58.37	1979, 1980, 1982, 1984, 1985,	1976, 1977
1986-1995	583.23	127.9	18.9	-35	-93.37	1986, 1987, 1989, 1992, 1993, 1995	1991, 1994,
1996-2005	720.41	68.3	9.5	137.18	43.81	NIL	1998, 2002, 2003,
2006-2015	677.3	283.3	41.8	-43.11	0.7	2008, 2011, 2015	2006, 2010

Source: Author's Computation, 2017

The result in Table 1 shows that twenty-eight (28) years recorded annual rainfall with 10% departure below the long-term mean of 676.6mm (<-10%) while twenty-six (26) years recorded annual rainfall with 10% departure greater than the long-term mean (>+10%) . It could be inferred from Table 1 that the decade 1996-2005 did not record rainfall with up to 10% departure below the long-term mean. Similarly, there was no year with 10% departure greater than the long-term mean of 676.6mm over the decade 1966 to 1975 in Sokoto. The first decade (1926-1935) has the highest number of years with 10% departure greater than the long-term mean over the period 1926 to 2015 in Sokoto. In contrast, the decade 1986-1995 has the highest number of years with 10% departure below the long-term mean over the period 1926-2015 in Sokoto (see Table 1). The 10% departure below the long-term mean (<-10%) over the period (1926-2015) indicates shortage of rainfall below the expected mean annual rainfall in the affected years in Sokoto. A situation that can seriously affect the rain-fed agriculture and other critical sector that required adequate rain water in Sokoto state. On the other hand, the 10% departure above (>+10)

the long-term mean over the period 1926-2015 indicates adequate water for rain-fed agriculture, ecological functioning and other uses in the in the affected years in Sokoto state.

Variability in the Numbers of Monthly Rainfall in Sokoto

The number of monthly rainfall for the period of ninety years in Sokoto was examined. It could be observed from Figure 2 that the years with six months of rainfall during the period 1926-2015 in Sokoto account for 36 (40%). The years with seven months rainfall during the period account for 32, (36%) the years with five months of rainfall occurrence account for 18 (20%). The years with eight months of rainfall during the period are three (3.3%) and only one year (1.1%) had nine months of rainfall (Figure 2). It is important to note that only 3-4 months (June, July, August and September) during the period recorded significant rainfall. The amount of rainfall recorded in other months (April, May and October) is not significant enough even for crop germination because most of the rainfall in those months were below 1mm.

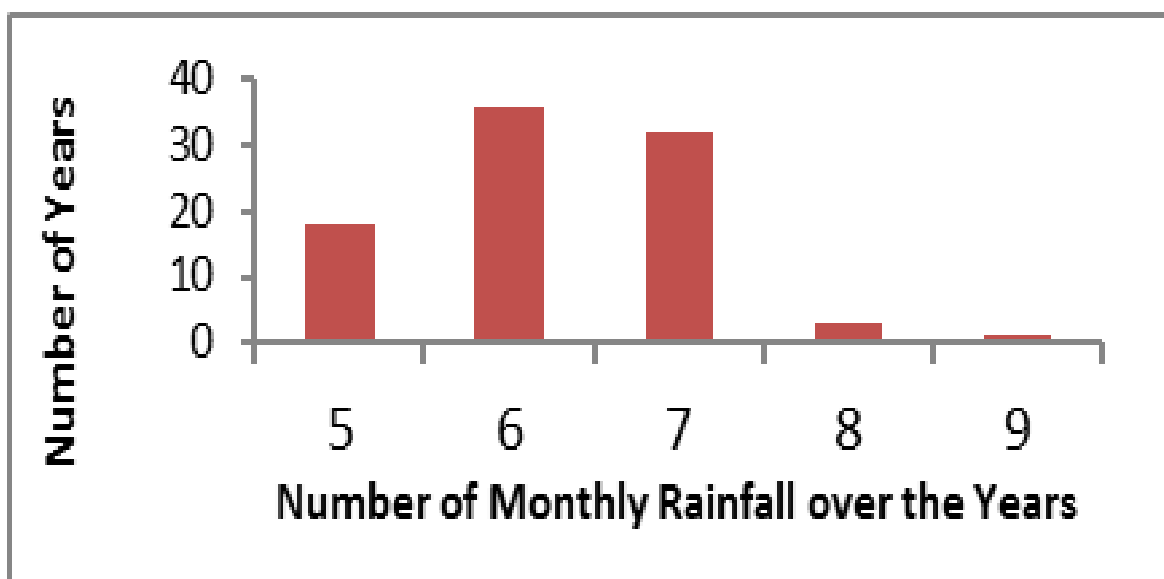


Figure 2: Number of Monthly Rainfall Occurrences over the Period 1926-2015

Trend of Annual Rainfall in Sokoto

The annual rainfall trend in Sokoto is depicted in Figure 3-11. It could be observed that the annual rainfall showed an upward trend in the first decade (1926-1935), fourth decade (1956-1965) and seventh decade (1986-1995) in Sokoto. On the contrary, the annual rainfall showed a downward trend in the second decade (1936-1945), third decade (1946-1955), fifth decade (1966-1975), sixth decade (1976-1985), eighth decade (1996-2005) and the ninth decade (2006-2015) see (Figure 2-9 for detail). On a general note, the annual rainfall in Sokoto showed a downward trend over the 90 years period (1926 to 2015). The result indicates that the total annual rainfall in Sokoto decrease at the rate of 0.909mm per annum. It means the total annual rainfall showed a downward trend of -81.81mm during the ninety years period (1926-2015) in Sokoto

(see Figure2). It is very important to note that the general downward trend observed in annual rainfall series over the period 1926-2015 is due to the influence of the catastrophic droughts of the 1940s, 1970s and 1980s where rainfall in most stations across the Sahel witnessed a remarkable reduction in their annual rainfall records. However, on a decadal basis, annual rainfall show that rainfall increases by 47.71mm per decade. This positive decadal change in rainfall was due to strong influence of the recent rainfall recovery in the Sahel which began in 1998 and continued to the present time as reported by Nicholson (2005), Umar *et al* (2015) and Umar and Bako (2018). The coefficient of determination (R^2) on the trend line graphs indicates that the decrease in the annual rainfall over the period in Sokoto is not statistically significant.

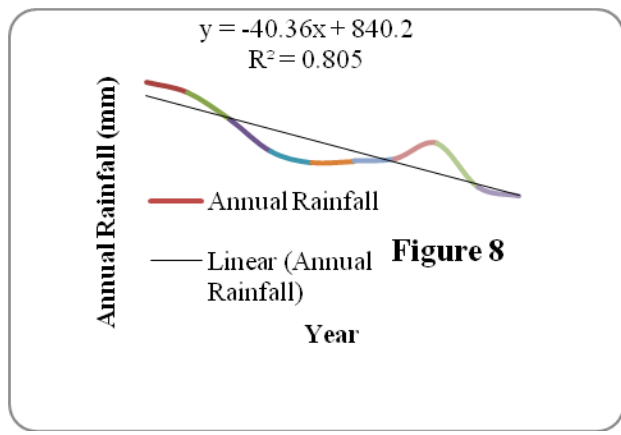
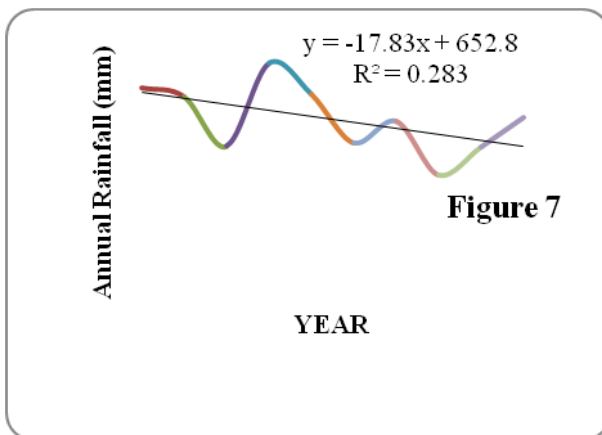
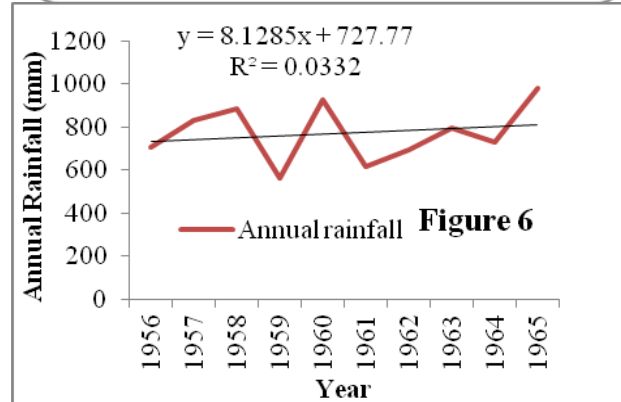
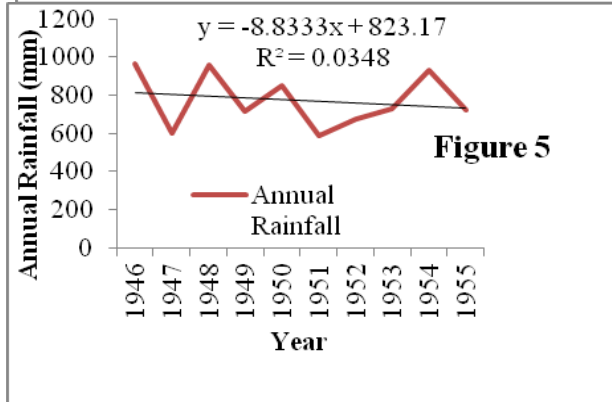
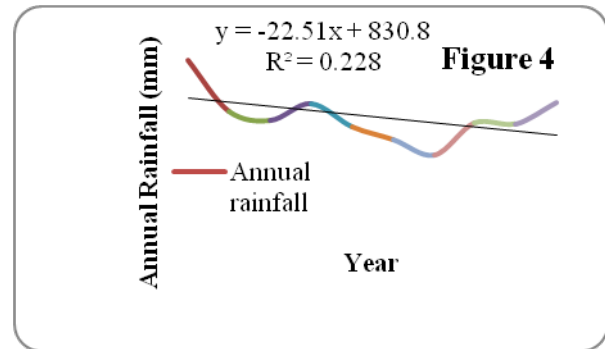
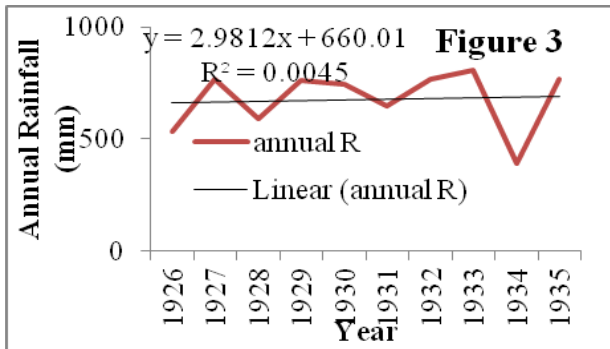


Figure 3-8: Annual Rainfall Trend Decade by Decade in Sokoto from (1926-1985)
Source: Author's Compilation, 2017

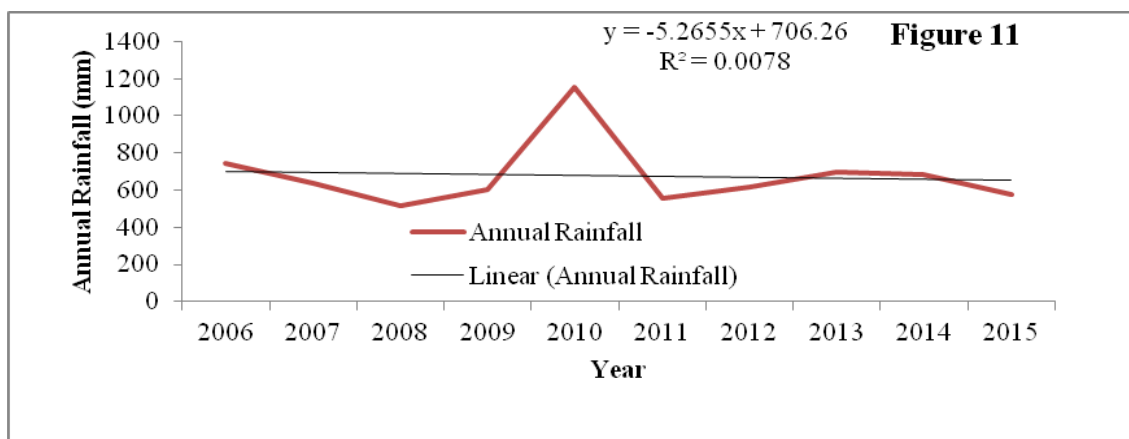
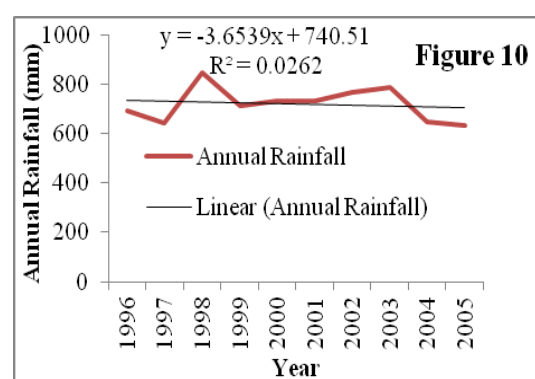
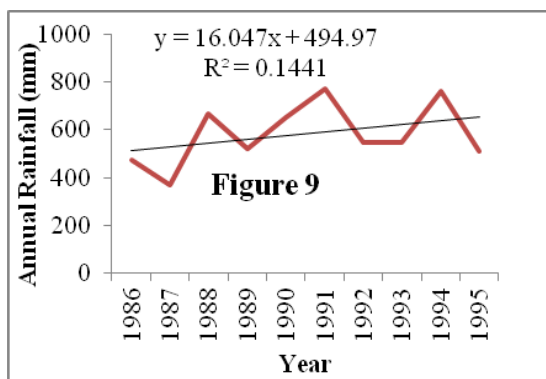


Figure 8-11: Annual Rainfall Trend Decade by Decade (continued) from 1986-2015) in Sokoto

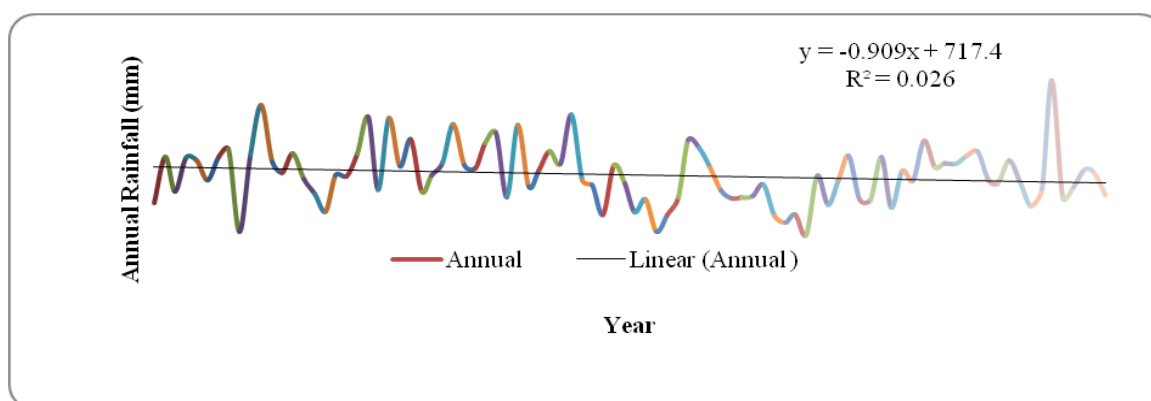


Figure 12: Annual Rainfall Trend in Sokoto for Ninety (90) Years (1926-2015)

Annual Variability in Rainfall in Sokoto

The annual rainfall departure from the long-term mean is contained in Table 2 and Figure 13. It could be observed that many of the years (52%) show a negative departure from the long-term mean of 676.6mm during the period of 1926 to 2015 in Sokoto. It could be inferred from Figure 13 that the years 1986 and 1987 show the highest negative departure of -305.9mm respectively from the long-term mean. This is followed by the year 1934 with a negative deviation of (-288.9mm) while the year 2010 shows the highest positive departure from the long-term mean (+473.6mm) followed by the

year 1936 with a positive departure of (+348.2mm). This higher positive rainfall departure from the long-term mean led to the devastating flood scenario in Sokoto in the year 2010. On the other hand, the years 1986, 1987, 1934 and 1973 that show the highest negative departure from the long term mean (see Figure 13) is an indication of drought in those particular years. That means the amount of rainfall recorded in these years were far below the mean annual rainfall, a situation that reduces the available water required for crop production and water uses in the state.

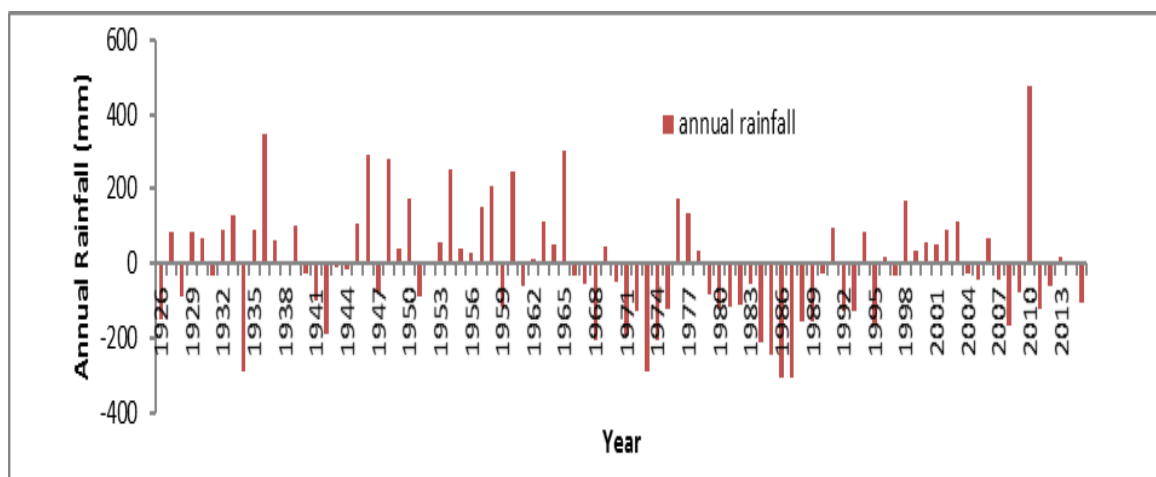


Figure 13: Rainfall anomaly in Sokoto for the Period of Ninety Years

Table 2: Annual Rainfall Departure from the Lon-term Mean of 676.6mm in Sokoto from 1926-2015

Year	Annual Rainfall Departure (mm)	Year	Annual Rainfall Departure (mm)	Year	Annual Rainfall Departure (mm)
1926	-146.3	1956	29.6	1986	-305.9
1927	86.8	1957	154.5	1987	-305.9
1928	-85.9	1958	210.5	1988	-154.2
1929	83.1	1959	-113.4	1989	-154.2

1930	67.2	1960	248.9	1990	-23.1
1931	-29.5	1961	-61.4	1991	94.5
1932	89	1962	15.5	1992	-128
1933	128.2	1963	116.2	1993	-128
1934	-288.9	1964	52.7	1994	85.1
1935	90.4	1965	301.7	1995	-167.2
1936	348.2	1966	-28.5	1996	16.2
1937	61.2	1967	-54.2	1997	-31.5
1938	7.6	1968	-203.7	1998	168.9
1939	104.7	1969	44.4	1999	34.6
1940	-24.1	1970	-48.8	2000	55.6
1941	-96.8	1971	-193.2	2001	54.8
1942	-187.6	1972	-127.9	2002	91.7
1943	-6.5	1973	-288.4	2003	113.2
1944	-11.9	1974	-204.2	2004	-27.5
1945	105.6	1975	-118.2	2005	-41.9
1946	292	1976	172.8	2006	68.5
1947	-77.4	1977	135	2007	-40.6
1948	283.2	1978	35.6	2008	-162.4
1949	39.4	1979	-81.4	2009	-76.7
1950	176.7	1980	-121	2010	473.6
1951	-85.8	1981	-116.7	2011	-119.2
1952	-3.8	1982	-108.8	2012	-61.5
1953	55.7	1983	-51	2013	21.6
1954	252.4	1984	-210	2014	3.3
1955	43.5	1985	-242.2	2015	-103.6

Source: Author's Computation, 2017

Conclusion

This study has examined the changing patterns of rainfall in Sokoto State for a period of ninety years (1926-2015) and the study concludes that the pattern of rainfall has changed over the years. There was variability in the rainfall and most of the years showed a negative departure from the long-term mean. The study equally discovers downward trends in the, annual, rainfall over the ninety years period in Sokoto, which is a strong indication that Climate Change is really

ravaging the area. Contrary to the general downward trend in the annual rainfall over the 90 years, the decadal changes showed positive changes. However, the general downward trend observed in the annual rainfall series over the period 1926-2015 was due to the influence of the catastrophic droughts of the 1940s, 1970s and 1980s where rainfall in most stations across the Sahel witnessed a marked reduction in their annual rainfall records. However,

on a decadal basis, annual rainfall showed that rainfall increases by 47.7mm per decade. This positive decadal change in rainfall was due to the strong influence of the recent rainfall recovery in the Sahel which began in 1998 and continued to the present as reported by Nicholson (2005), Umar et al (2015) and Umar and Bako (2018) The study thus recommends adequate and

accurate seasonal rainfall predictions to farmers especially, so that they can have sustainable plans to improve their crop production. The study also suggest that if the current rainfall trends in Sokoto State continues, there will be the need for more functional and sustainable irrigation schemes for efficient crop production in the State

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